

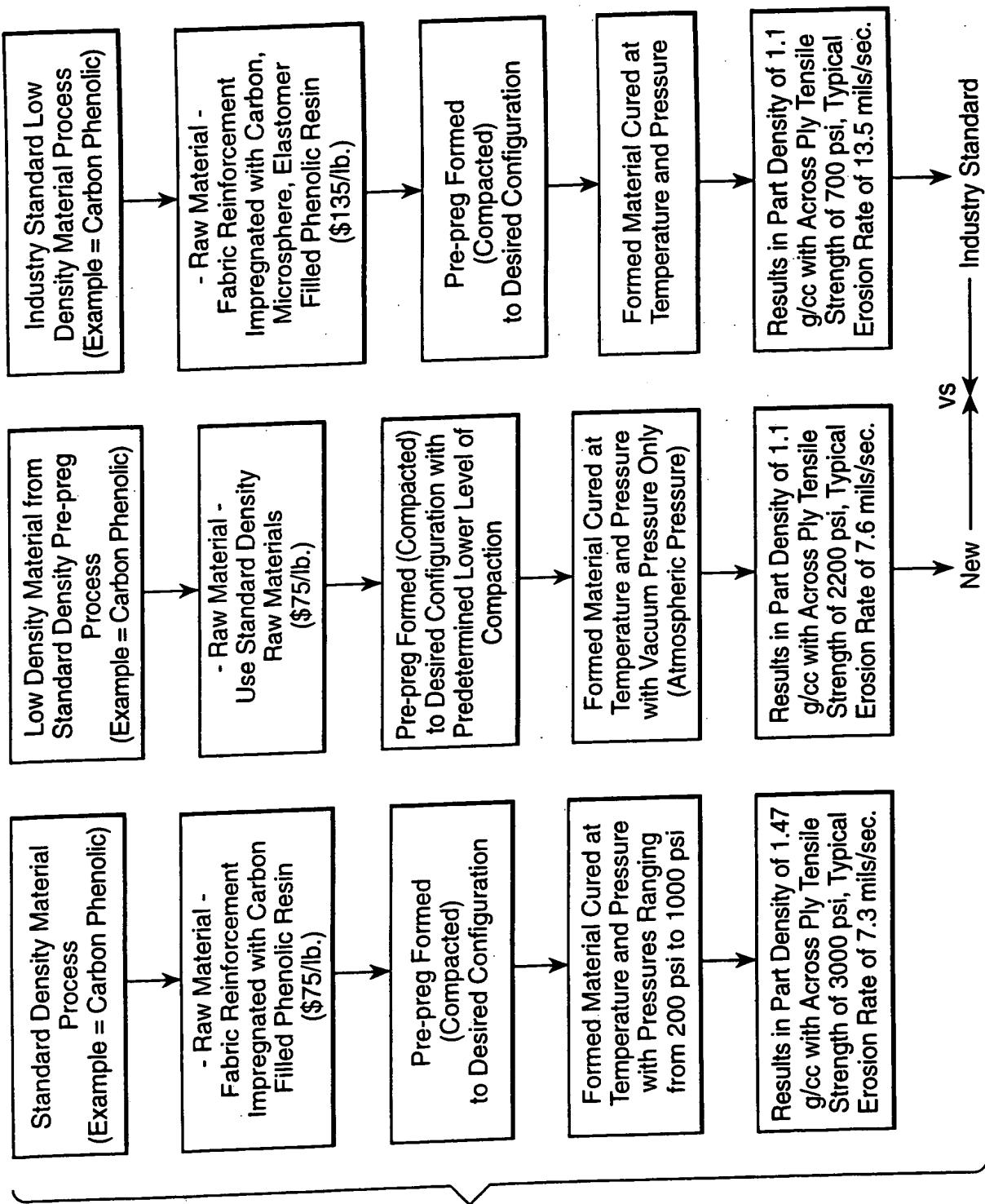
**LOW DENSITY COMPOSITE ROCKET NOZZLE  
COMPONENTS AND PROCESS FOR MAKING THE SAME ...**

Inventors: Allan P. Thompson et al.

Filed: November 25, 2003

Attorney Docket No. 5776.2US

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*Fig. 1*

LOW DENSITY COMPOSITE ROCKET NOZZLE  
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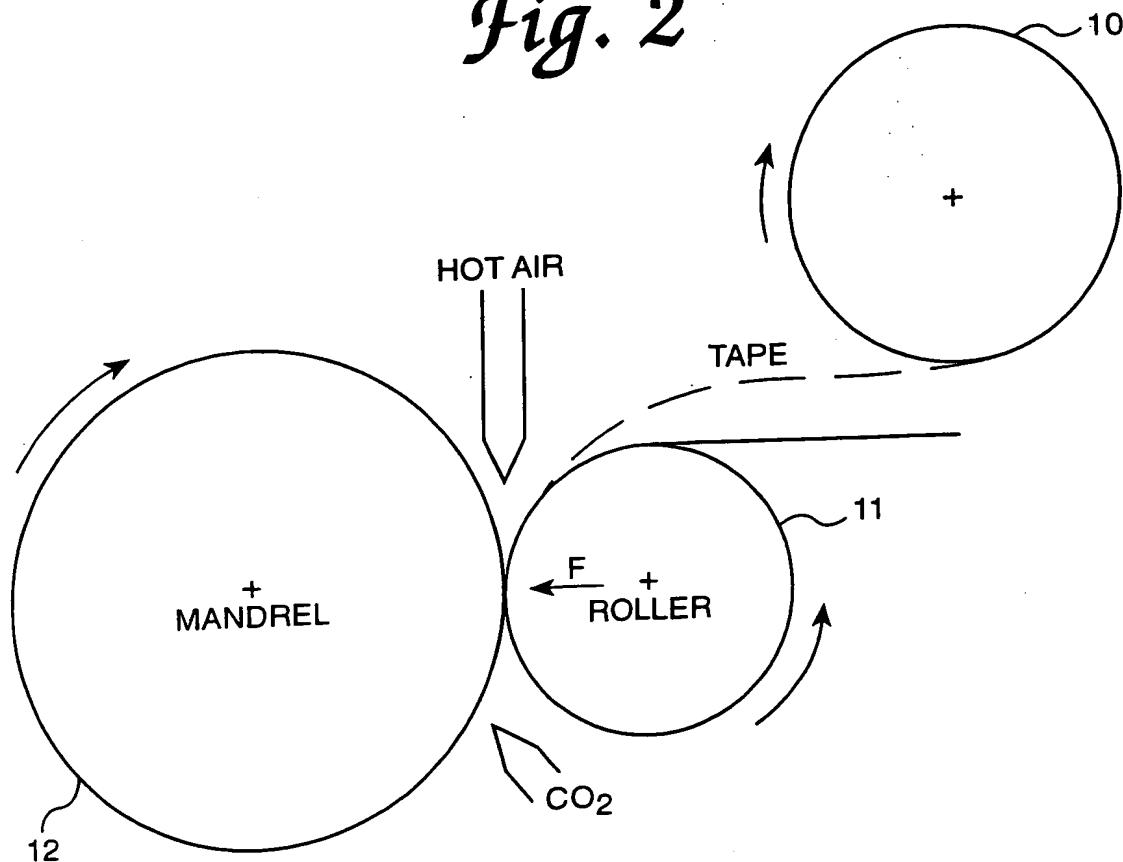
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*Fig. 2*



- A . A wrap mandrel is placed in the machine (a wrap machine looks much like a lathe).
- B . The tape application roller is set parallel to the wrapping surface of the mandrel.
- C . Tape is fed across the surface of the application roller
  - Pre-preg tape is heated with hot air as it crosses over the roller to soften the tape.
  - Pressure is applied through the roller to debulk the tape onto the wrap mandrel.
  - CO<sub>2</sub> from a liquid holding tank is applied to cool and harden the debulked tape.

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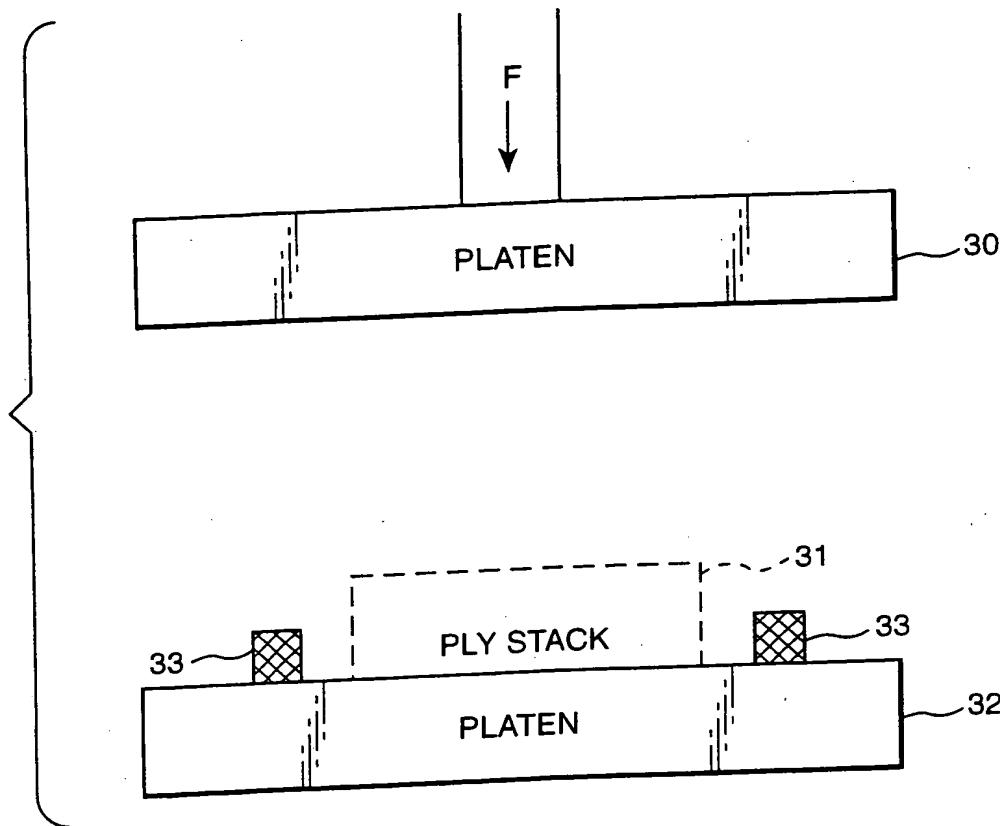
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*Fig. 3*

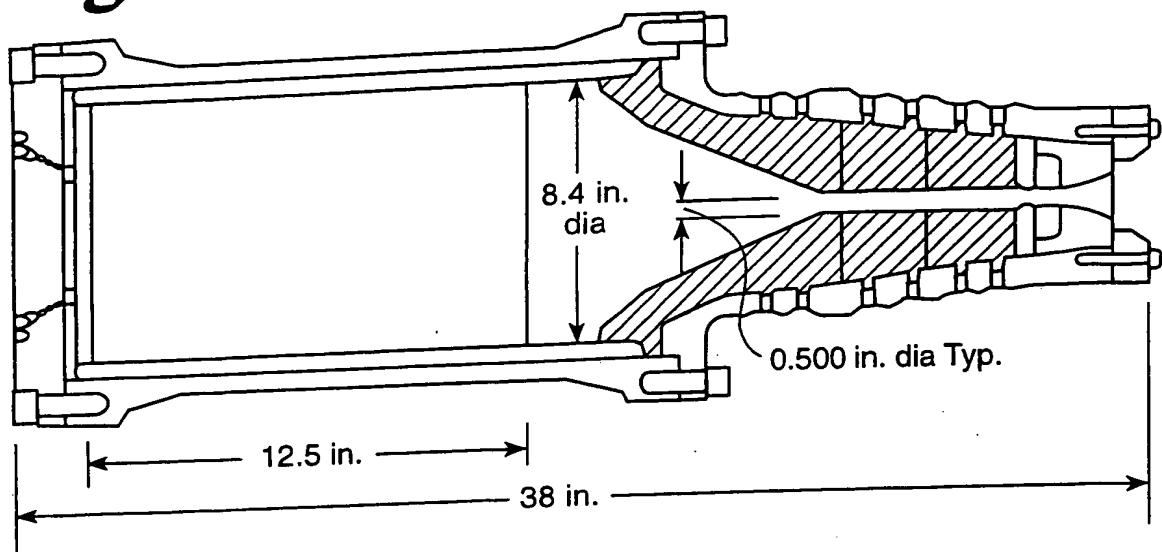


- A. A stack of plies is placed in the heated platen press for debulk.
  - Platen are warmed to 130 - 150°F to soften pre-preg.
  - Stops are set to restrict platen travel and to achieve desired debulked ply thickness.
- B. Press platens are closed to stops and held at temperature for 20 min.
- C. Debulked stacks are cooled to room temperature before opening platens.
- D. Debulked stacks are stacked to form entire billet.

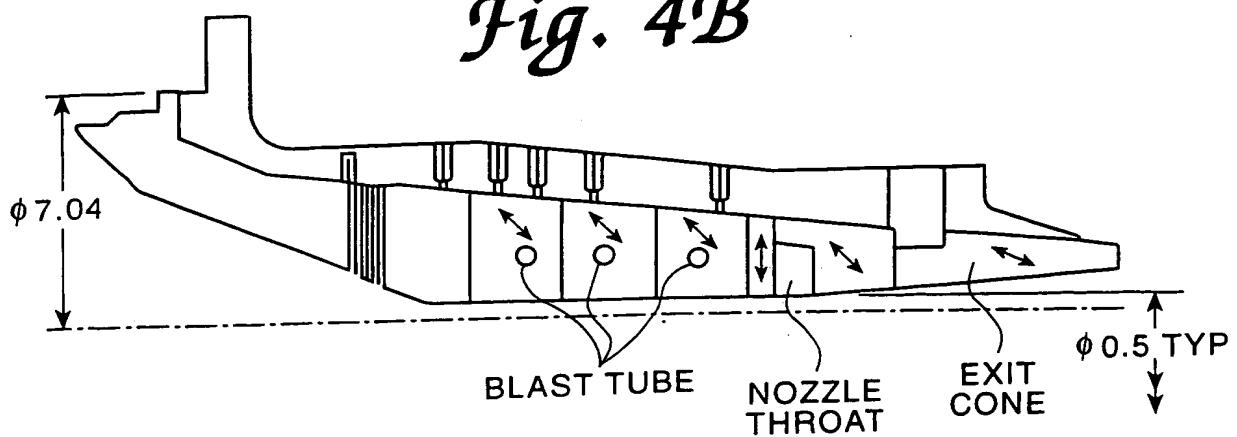
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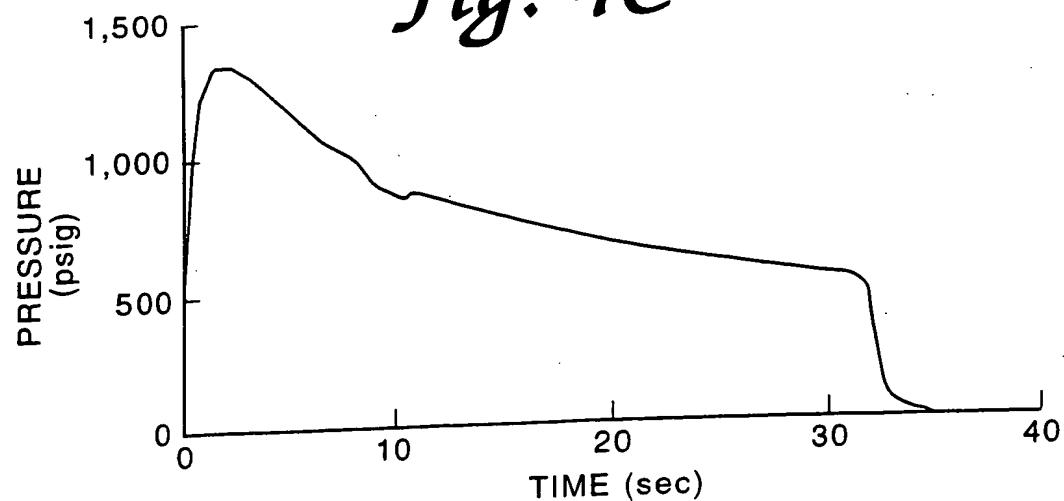
*Fig. 4A*



*Fig. 4B*



*Fig. 4C*



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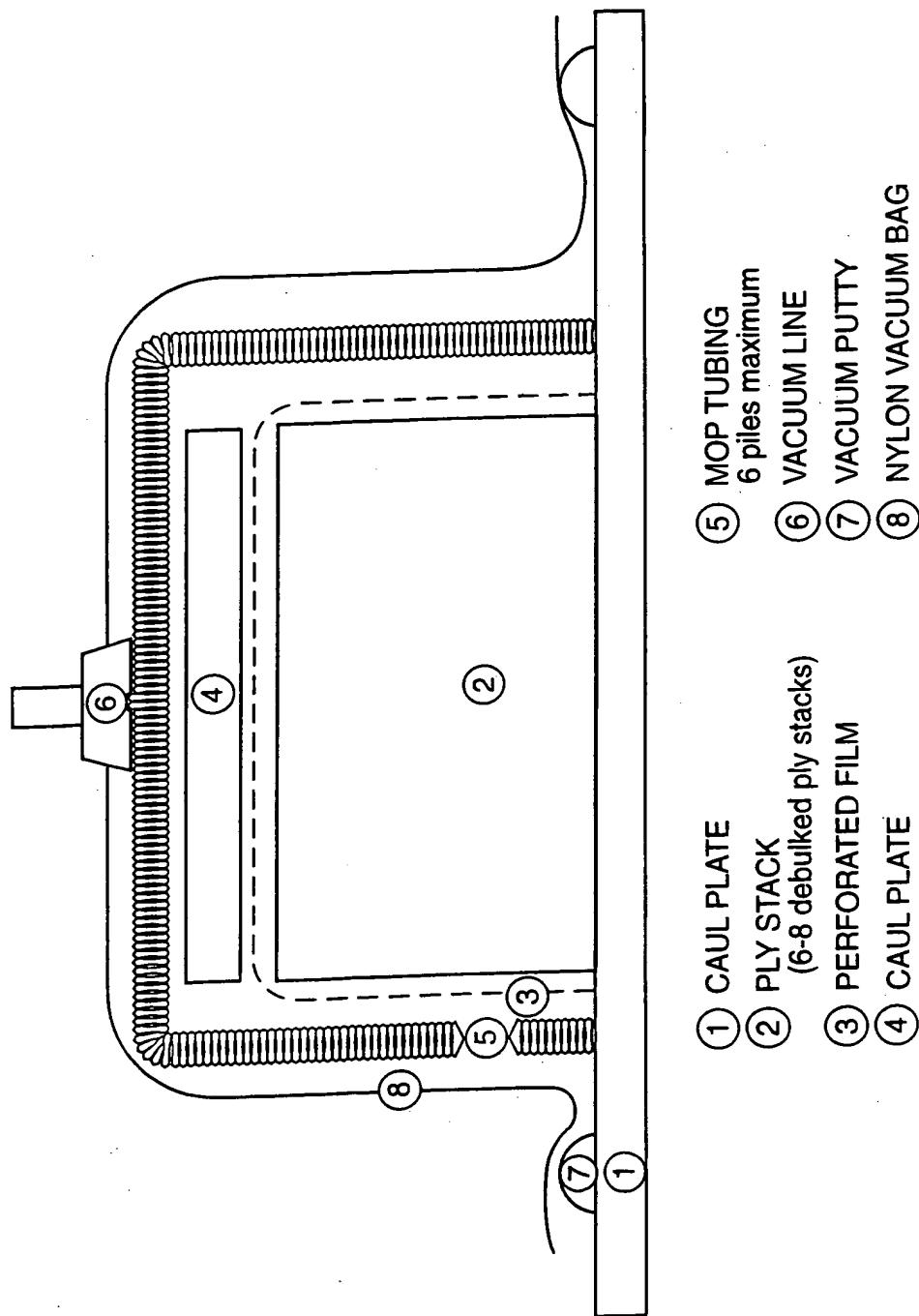
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Fig. 5



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Component	Motor	Material	Norm. Erosion, mils/s	Norm. Char. inches	Total Heat Affected Depth, inches
Blast Tube-Aft	MPCE-1	MX-4946	2.39	0.409	0.493
	MPCE-2	MX-4926 VC	7.59	0.268	0.534
	MPCE-3	MX-4920 VC	6.18	0.464	0.680
	MPCE-4	UF MX-134 LDR (1.2)	11.03	0.234	0.620
	MPCE-5	UF MX-4920	5.32	0.483	0.669
	MPCE-6a	FM-32800 LD/LF	12.18	0.255	0.681
	MPCE-6b	MX-4955	8.65	0.398	0.701
	MPCE-7	MX-4946 VC	6.10	0.386	0.599
	MEAN	MX-4926	7.25	0.283	0.537
Blast Tube-Mid	MPCE-1	MX-4946	9.32	0.464	0.790
	MPCE-2	MX-4926 VC	10.49	0.301	0.668
	MPCE-3	MX-4920 VC	6.56	0.761	0.991
	MPCE-4	UF MX-134 LDR (1.2)	15.60	0.299	0.845
	MPCE-5	UF MX-4920	9.28	0.582	0.907
	MPCE-6	FM-32800 LD	13.97	0.205	0.694
	MPCE-7	MX-4946 VC	8.22	0.496	0.784
Blast Tube-Fwd	MPCE-1	MX-4946, 45	5.88	0.278	0.484
	MPCE-2		7.30	0.246	0.502
	MPCE-3		6.16	0.319	0.535
	MPCE-4		7.67	0.244	0.512
	MPCE-5		7.71	0.322	0.592
	MPCE-6		9.16	0.283	0.604
	MPCE-7		6.90	0.288	0.530
	MEAN	MX-4926	7.25	0.283	0.537
Throat	Typical	4D C/C . 1.95 gm/cc	2.50		
	MPCE-1	4D C/C . 1.90 gm/cc	1.20		
	MPCE-2	RTM'd 4D C/C, 1.75 gm/cc	6.12		
	MPCE-3	Componient Hf/2W	0.81		
	MPCE-4	2D C/C Brake, 1.87 gm/cc	3.98		

Fig. 6A

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Component	Motor	Material	Norm. Erosion, mils/s	Norm. Char. inches	Total Heat Affected Depth, inches
Throat	MPCE-5 MPCE-6 MPCE-7	HfC on Poco Graphite ZIRCONIUM DIBORIDE In situ C/C by PL RD	7.26 7.76 5.01		
Throat Inlet	MPCE-1 MPCE-2 MPCE-3 MPCE-4 MPCE-5 MPCE-6 MPCE-7	MX-4926, 90	6.73 9.94 8.97 7.50 11.90 8.76 7.41	0.341 0.364 0.562 0.617 0.700 0.330	0.543 0.678 0.896 1.033 0.963 0.589
Forward Exit Cone	MPCE-1 MPCE-2 MPCE-3 MPCE-4 MPCE-5 MPCE-6 MPCE-7	MX-4946, 45	4.24 4.00 12.74 4.62 3.72 4.73 3.42	0.216 0.260 0.216 0.211 0.340 0.190 0.297	0.364 0.400 0.682 0.350 0.430 0.356 0.417
Aft Exit Cone	C4-7 MPCE-1 MPCE-2a MPCE-2b MPCE-3a MPCE-4a MPCE-4b MPCE-5a MPCE-5b MPCE-6a MDCE-6b MPCE-7a MPCE-7b	MX-4946 MX-4926 MX-4920 VC MX-4926 VC UF MX-4920 VC UF MX-4920 UF MX-134 LDR (1.2) UF MX-4920 VC & PC FM-32800 LD/LF UF MX-134 LDR (1.2) PC 4.57 4.11 4.15 4.94 4.93 3.24 3.42	7.65 4.22 3.05 5.42 6.73 6.37 4.54 4.57 4.11 4.15 4.94 4.93 3.24 3.42	0.295 0.193 0.219 0.269 0.254 0.292 0.272 0.344 0.285 0.258 0.352 0.270 0.420 0.360	0.563 0.341 0.326 0.459 0.677 0.991 0.431 0.504 0.429 0.400 0.525 0.443 0.534 0.484

**Fig. 6B**

LOW DENSITY COMPOSITE ROCKET NOZZLE  
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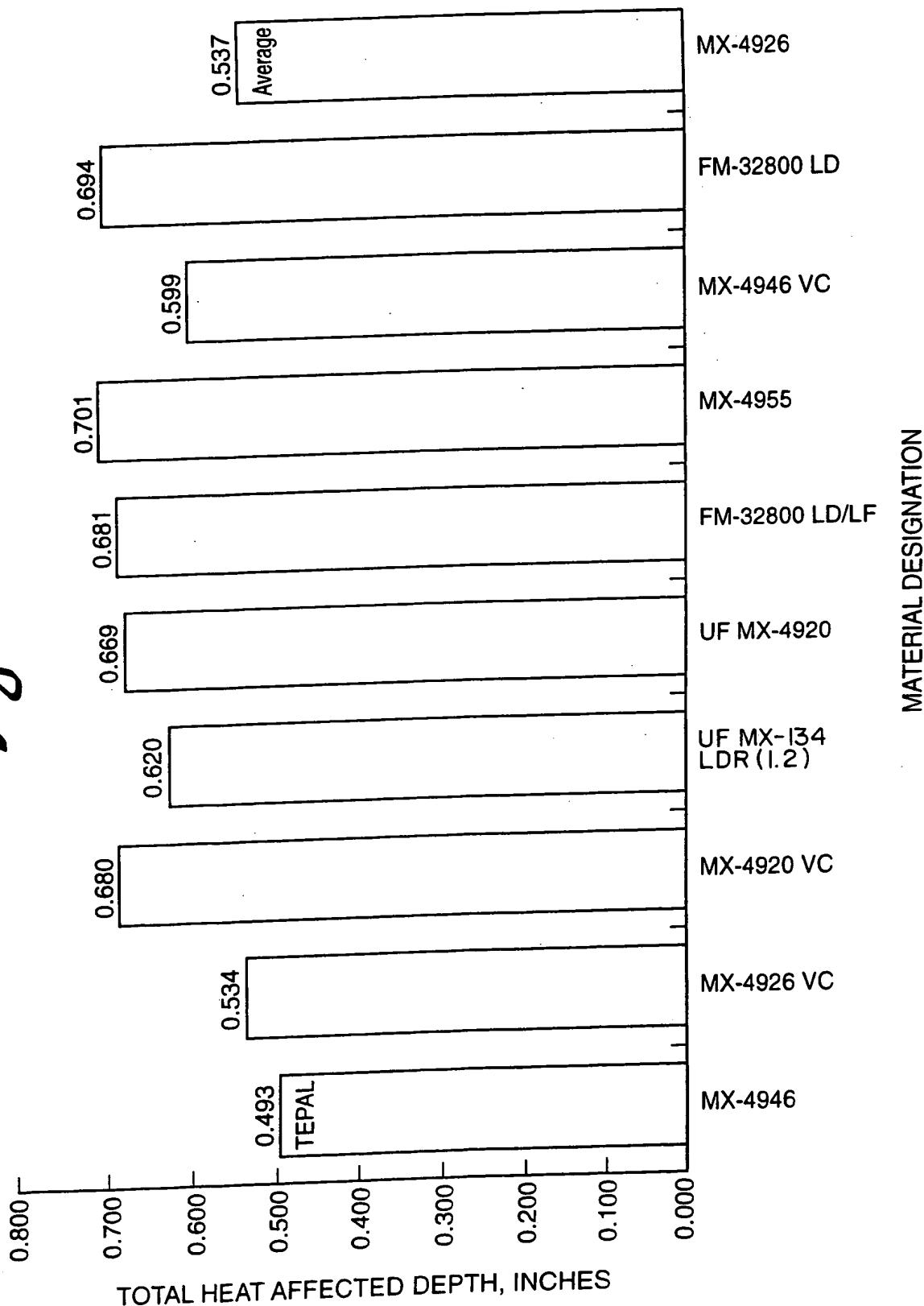
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*Fig. 7*



LOW DENSITY COMPOSITE ROCKET NOZZLE  
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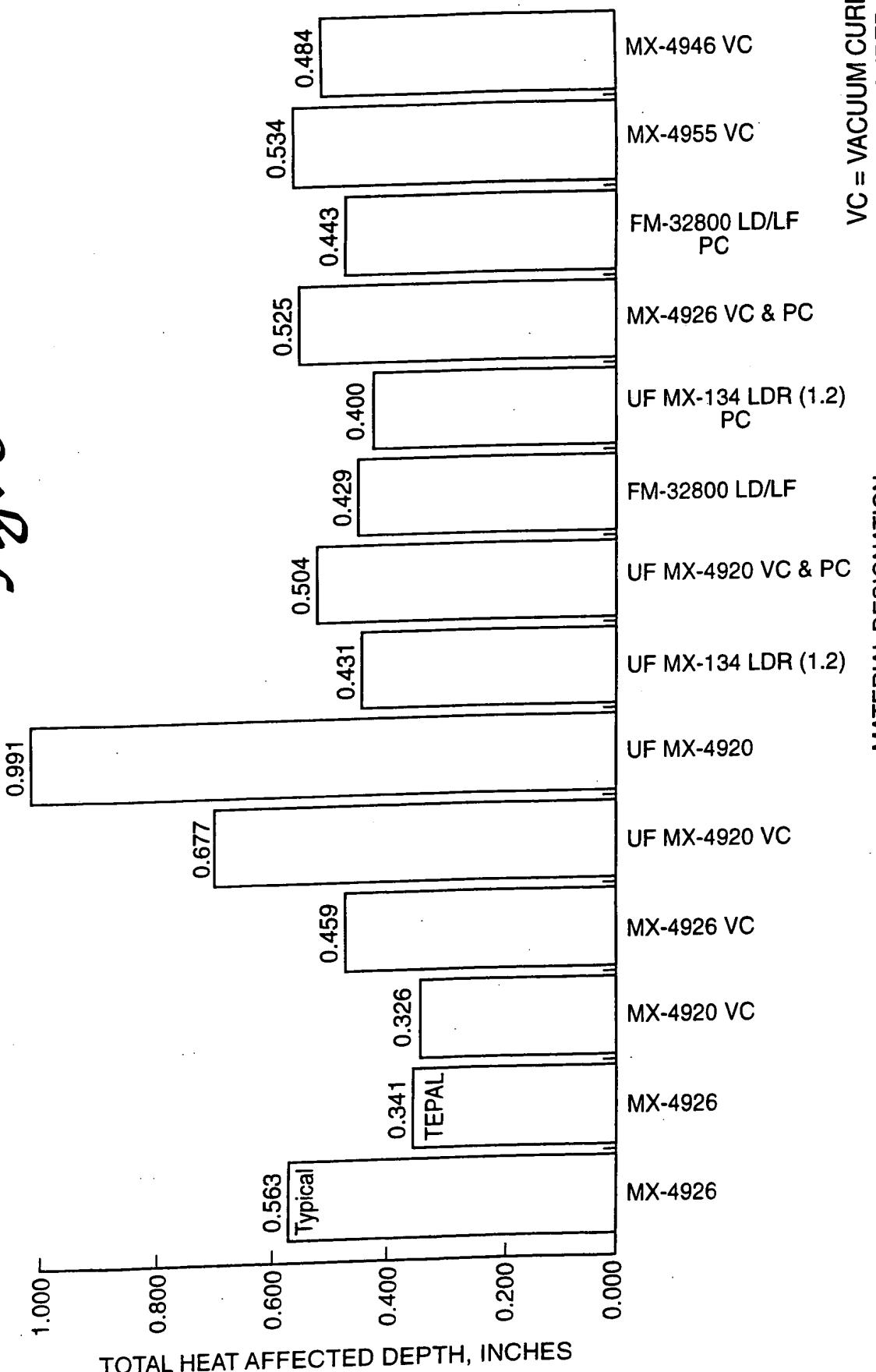
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Fig. 8



LOW DENSITY COMPOSITE ROCKET NOZZLE  
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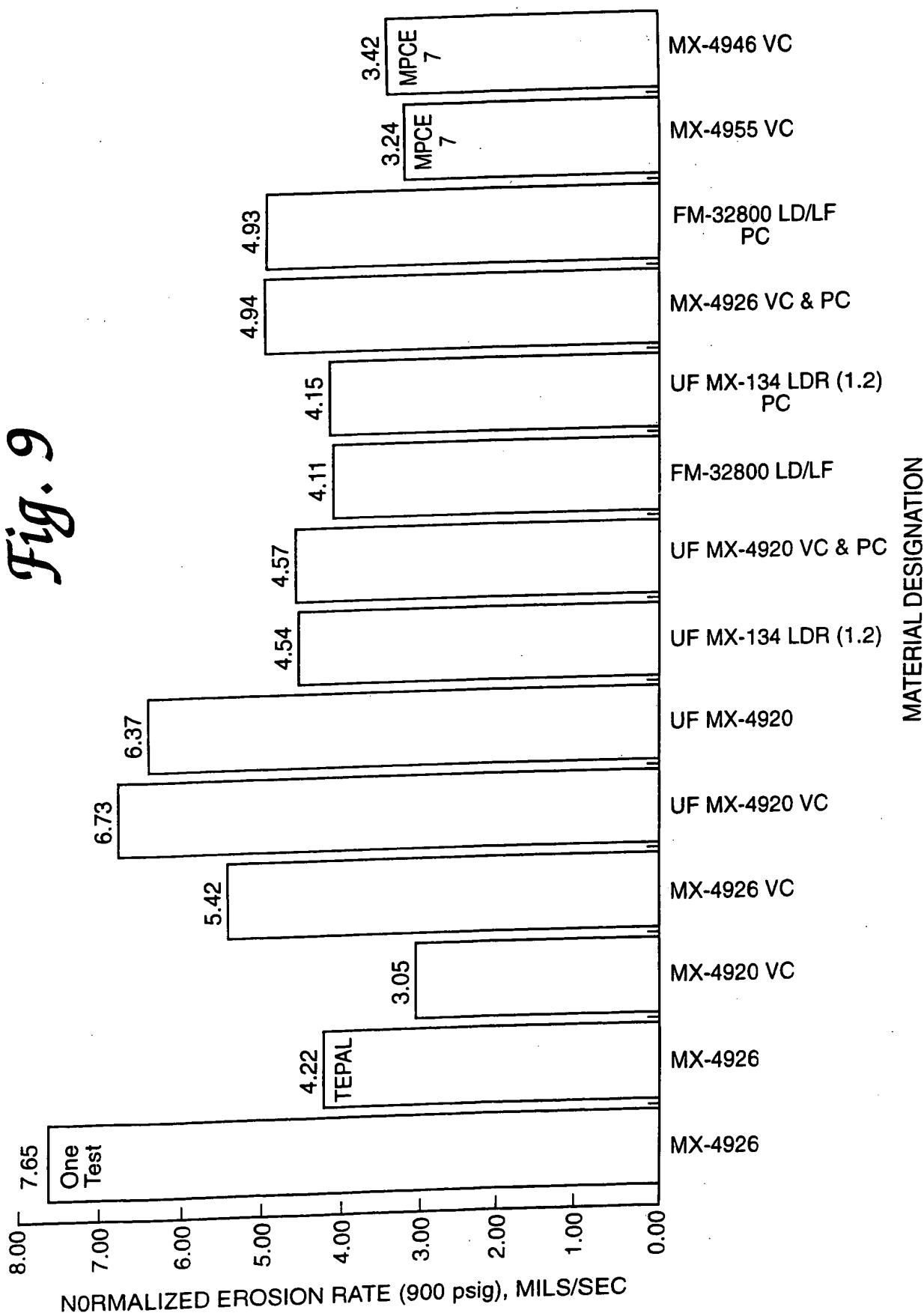
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Fig. 9



# LOW DENSITY COMPOSITE ROCKET NOZZLE COMPONENTS AND PROCESS FOR MAKING THE SAME ...

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*Fig. 10A*

Location	Motor	Material	Bulk Density, gm/cc	Specific Gravity	Residual Volatiles, wt%	Resin Content, wt%	Compressive Strength, psi	Norm. Erosion mils/s	Norm. Char, inches	Thad, inches
Blast Tube, 45	MPCE-1	MX-4946	1.495	1.525	2.14	31.29	21379	2.39	0.409	0.493
	MPCE-2	MX-4926 VC	1.142	1.167	2.27	33.04	19749	7.59	0.268	0.534
	MPCE-3	MX-4920 VC	1.383	1.434	0.30	27.18	23067	6.18	0.464	0.680
	MPCE-4	UF MX-134 LDR	1.211	1.241	1.81	41.48	18520	11.03	0.234	0.620
	MPCE-5	UF MX-4920	1.454	1.496	1.94	33.23	17057	5.32	0.483	0.669
	MPCE-6	FM-32800 LD/LF	1.193	1.227	1.00	29.36	17132	12.18	0.255	0.681
		FM-32800 LD	1.184	1.216	1.52	30.65	27134	13.97	0.205	0.694
		MX-4955	1.510	1.547	2.53	27.95	13922	8.65	0.398	0.701
	MPCE-7	MX-4946 VC	1.374	1.440	0.67	35.68	29802	6.10	0.386	0.599
	MPCE-1,2,3	MX-4926	1.449	1.478	0.68	35.65	41850			
	MPCE 4 - 7	MX-4926	1.458	1.487	0.88	36.29				
Blast Tube, 90	Mean	MX-4946	1.454	1.484	0.78	35.97	41850	7.25	0.283	0.537
	MPCE-1	MX-4926 VC	1.510	1.538	2.06	30.63	22546	9.32	0.464	0.790
	MPCE-2	MX-4920 VC	1.142	1.176	0.80	32.01		10.49	0.301	0.668
	MPCE-3	UF MX-134 LDR	1.411	1.455	0.48	27.95	28732	6.56	0.761	0.991
	MPCE-4	UF MX-4920	1.207	1.239	1.83	41.19	22119	15.60	0.299	0.845
	MPCE-5	UF MX-4920	1.459	1.503	1.93	31.72	21108	9.28	0.582	0.907
	MPCE-7	MX-4946 VC	1.406	1.439	1.99	32.72	27145	8.22	0.496	0.784

# LOW DENSITY COMPOSITE ROCKET NOZZLE COMPONENTS AND PROCESS FOR MAKING THE SAME ...

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*Fig. 10B*

Location	Motor	Material	Bulk Density, gm/cc	Specific Gravity	Residual Volatiles, wt%	Resin Content, wt%	Compressive Strength, psi	Norm. Erosion mils/s	Norm. Char, inches	Thad, inches
Aft Exit Cone	MPCE-1	MX-4946	1.463	1.483	0.65	36.45		4.22	0.193	0.341
	MPCE-2	MX-4926 VC	1.097	1.144	0.39	31.83		5.42	0.269	0.459
	MPCE-3	MX-4920 VC	1.424	1.468	0.67	28.01		3.05	0.219	0.326
		UF MX-4920	1.458	1.504	2.84	28.44	18718	6.73	0.254	0.677
		UF MX-4920 VC	1.368	1.415	1.42	33.73	22534	6.37	0.292	0.991
	MPCE-4	UF MX-134 LDR	1.212	1.243	1.85	40.97		4.54	0.272	0.431
		UF MX-4920 VC/PC	1.324	1.396	0.06	31.66	20583	4.57	0.344	0.504
MPCE-5	FM-32800 LD/LF	1.098	1.190	0.80	27.45	16646	4.11	0.285	0.429	
	UF MX-134 LDR PC	1.212	1.245	2.02	42.29	16759	4.15	0.258	0.400	
	MPCE-6	MX-4926 VC/PC	1.084	1.154	0.00	30.93	18195	4.93	0.299	0.525
		FM-32800 LD/LF PC	1.127	1.213	0.46	28.10	7748	4.94	0.365	0.443
	MPCE-7	MX-4955 VC	1.371	1.428	0.17	27.02	16872	3.42	0.398	0.484
		MX-4946 VC	1.323	1.412	0.13	35.44		3.24	0.450	0.534

*Fig. 11*

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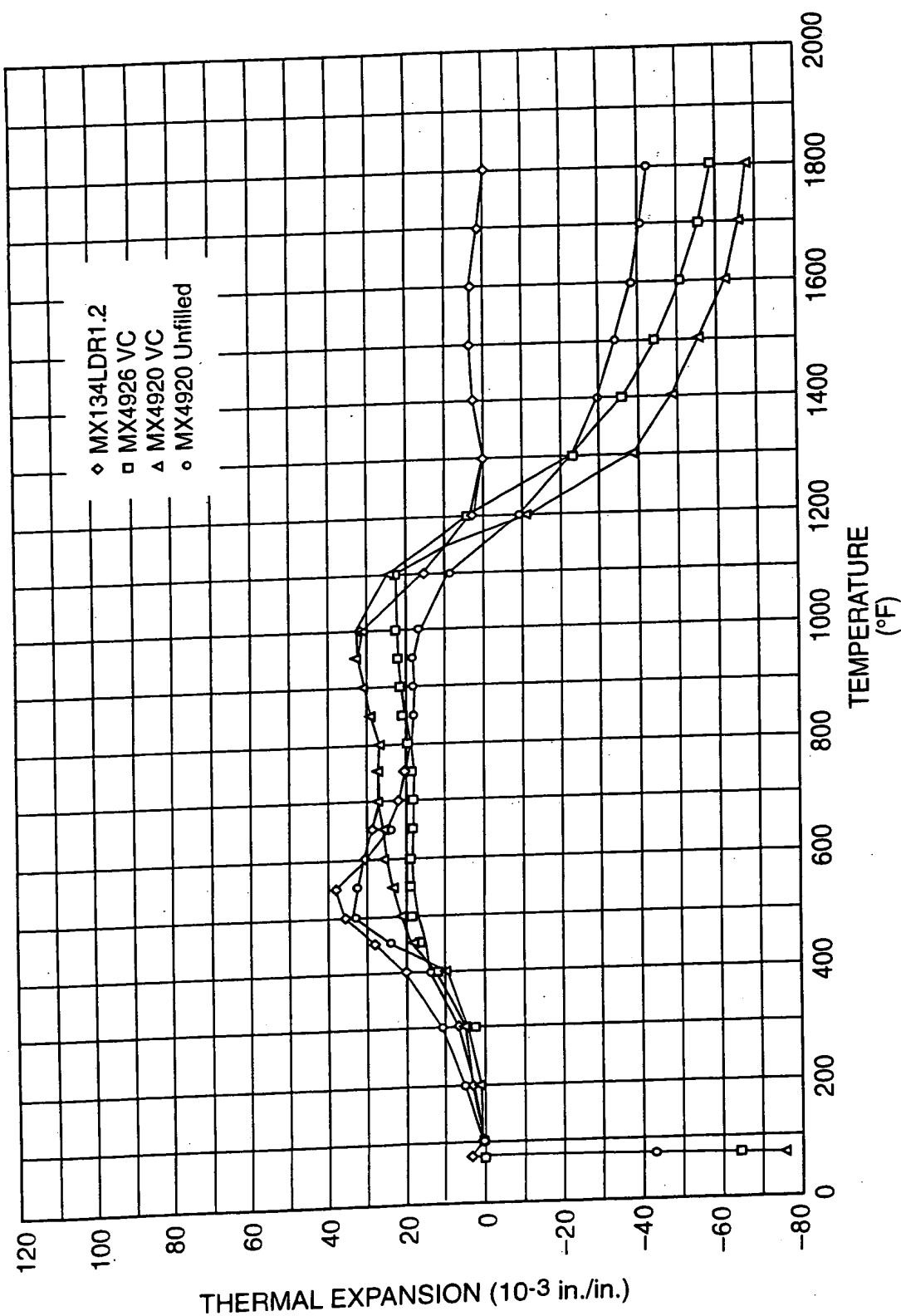
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Fig. 12



LOW DENSITY COMPOSITE ROCKET NOZZLE  
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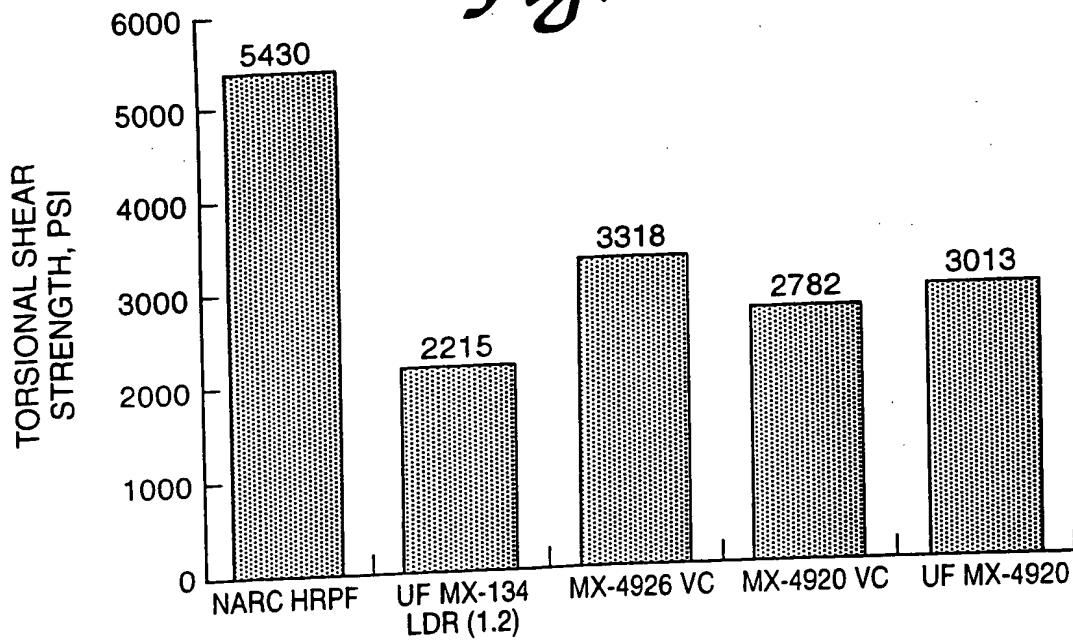
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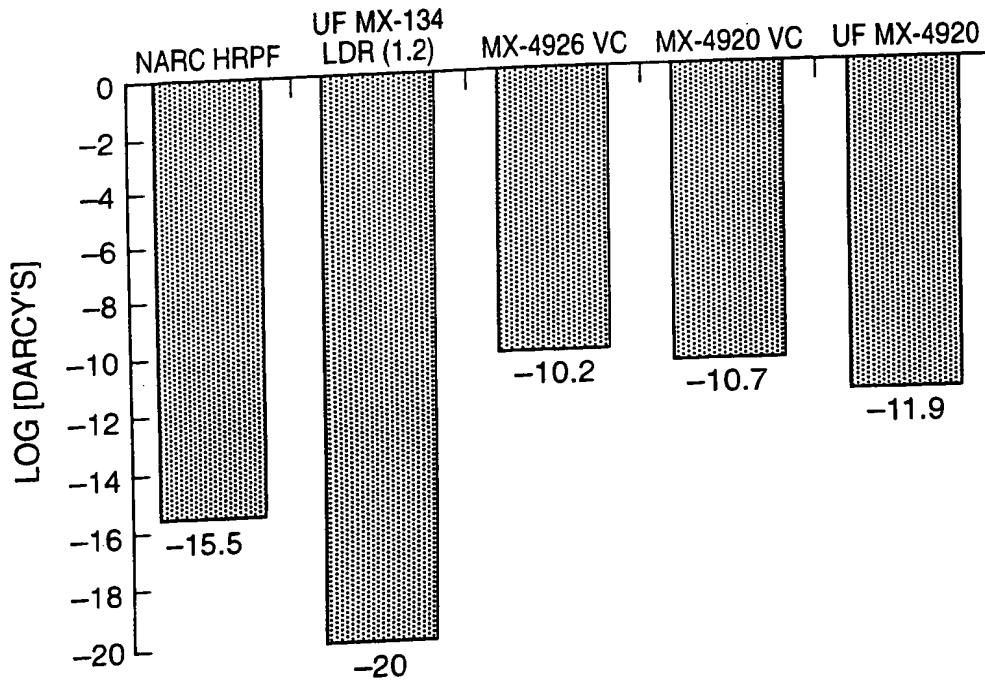
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*Fig. 13*



*Fig. 14*



LOW DENSITY COMPOSITE ROCKET NOZZLE  
COMPONENTS AND PROCESS FOR MAKING THE SAME ...

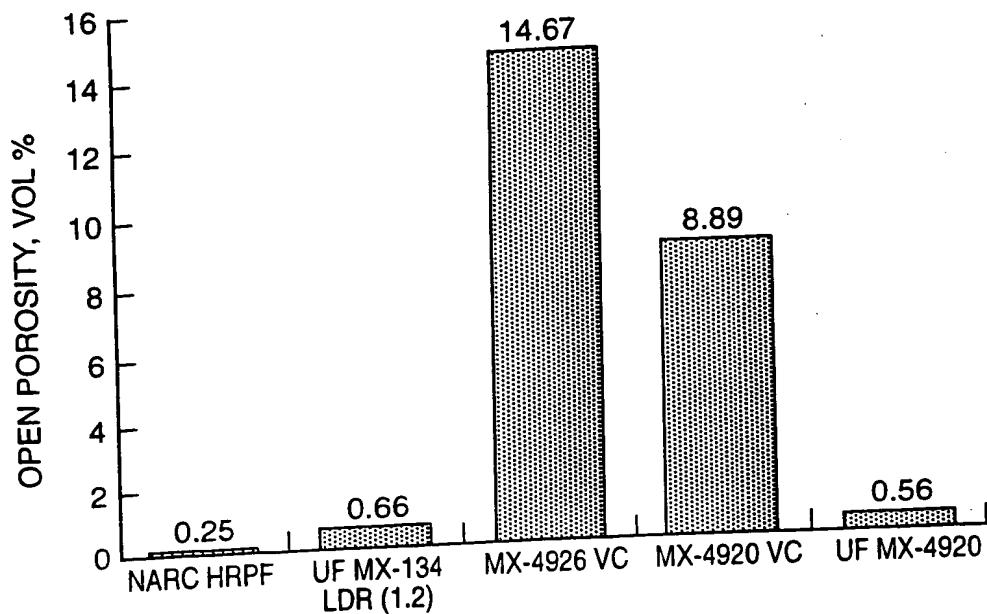
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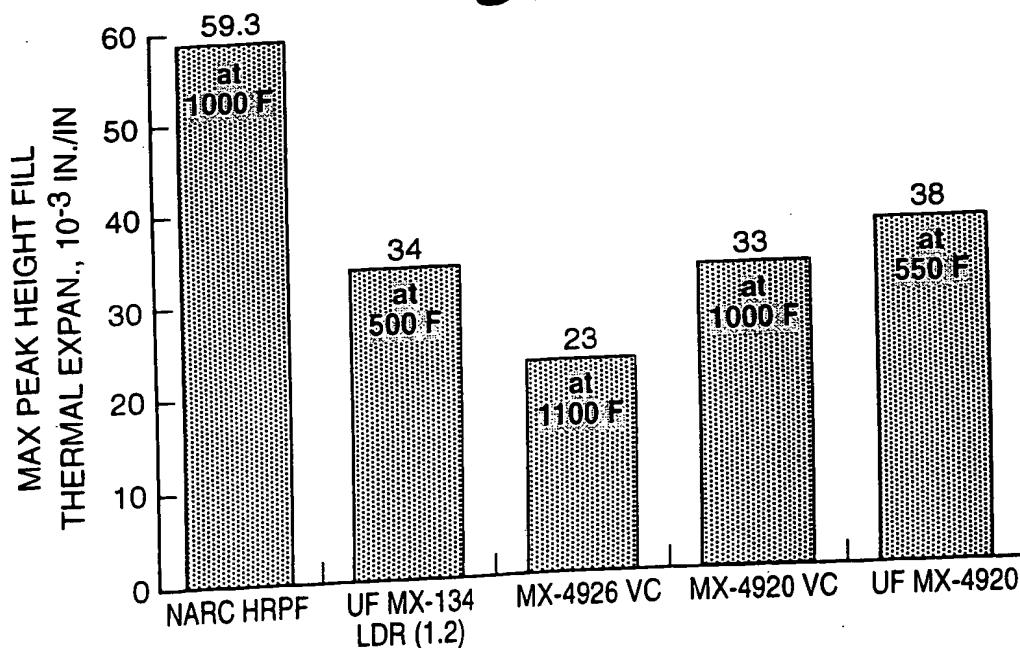
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*Fig. 15*



*Fig. 16*



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*Fig. 17*

